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(71) Applicant (*for all designated States except US*): **RAILPOWER TECHNOLOGIES CORP.** [CA/CA]; Suite 202, 50 Fell Avenue, North Vancouver, British Columbia V7P 3S2 (CA).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): **WATSON, John, David** [US/US]; 34804 West Meadow Road, Evergreen, CO 80439 (US).

(74) Agents: **SWARTZ, Douglas, W.** et al.; Sheridan Ross P.C., 1560 Broadway, Suite 1200, Denver, CO 80202-5141 (US).

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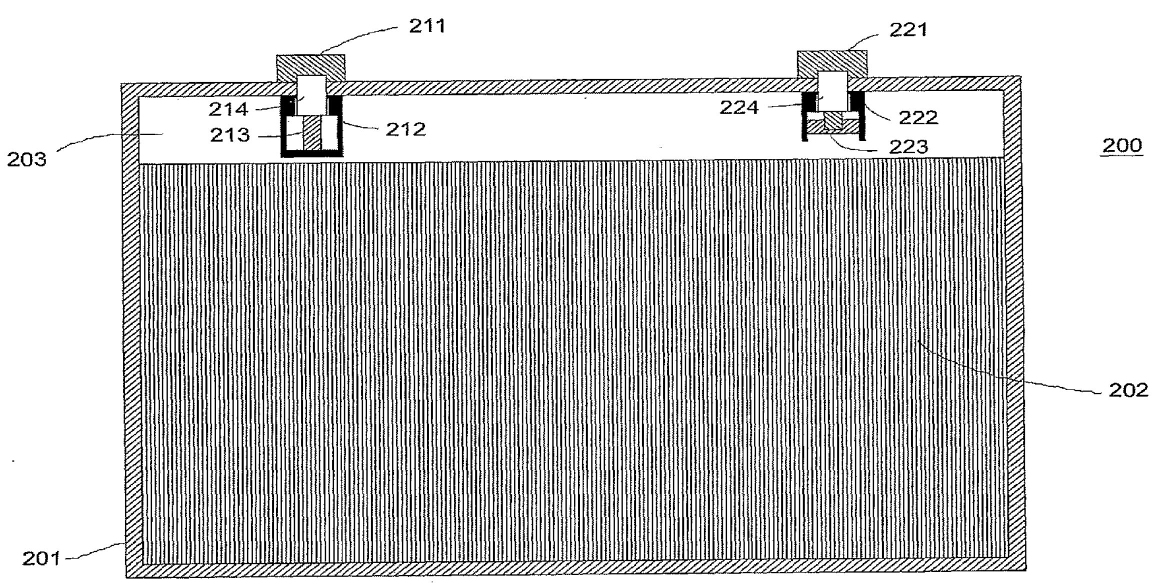
(54) Title: AUTOMATED BATTERY CELL SHUNT PYPASS




(57) Abstract: A battery pack is provided that includes a plurality of battery cells electrically connected in series, the plurality of battery cells including a selected battery cell, and a shorting mechanism operable, upon the occurrence of a selected event, to automatically remove electrically the selected battery cell from the electrically connected battery cells.

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# AUTOMATED BATTERY CELL SHUNT BYPASS

## FIELD

The present invention relates generally to a method for automatically electrically removing individual battery cells which are malfunctioning from a battery pack of cells electrically connected in series.

## BACKGROUND

Batteries, in particular large lead-acid batteries, are typically fabricated first by arranging a series of positive and negative plates separated by a separator material in a stack. Positive and negative bus bars are typically welded to positive and negative tabs that extend from the tops of the positive and negative plates respectively. The positive and negative terminals of the battery are typically fabricated as part of the bus bar assembly. The separator material is impregnated with an appropriate electrolyte and the top of the battery case is installed.

When a large number of cells are used in a series-connected battery pack configuration (the cell voltages add, the battery pack current is the same as the individual cell currents), one cell that begins to degrade or fail can seriously impact or terminate the operation of the entire battery pack. It is therefore desirable to have a means where a malfunctioning cell in a series-connected battery pack can be automatically removed from the battery pack.

In a battery pack, degraded or failed plate pairs in a malfunctioning cell can be open-circuited by utilizing a fuse mechanism to remove one of more electrode pairs in the affected cell from service. The open-circuit approach typically applies to electrode pairs that are in parallel in a cell. This leaves a smaller number of plate pairs in the cell. The disadvantage of this approach is the additional cost and complexity of having a fuse mechanism on each plate pair, and a reduction in the maximum current available from the battery pack since all cells must be derated to the performance parameters of the cell with the shorted plate pair or pairs. This approach can also cause in imbalance in the state-of-charge (“SOC”) between cells which can lead to loss of cell lifetimes.

Another approach is to use a battery management system where the battery pack performance is reduced to the level of the degraded or failing cell. This approach limits the

maximum available pack current as well as the available storage capacity and output voltage of the pack to match the capability of the malfunctioning cell.

A third approach is to short-circuit a malfunctioning cell to eliminate the cell from the battery pack by shunting pack current around the malfunctioning cell. This approach has the advantage of not reducing the maximum available battery pack current. In a large battery pack which may be comprised of several hundred cells in series, there will be a small reduction in battery pack voltage and ampere-hour capacity when one or a few cells are bypassed.

Thus there is a need for a low cost method to automatically shunt out malfunctioning cells in a large series connected battery pack to avoid seriously impacting or terminating the operation of the entire battery pack.

## SUMMARY

These and other needs are addressed by the various embodiments and configurations of the present invention which are directed generally to a method for automatically electrically removing individual battery cells which are malfunctioning from a series string of cells.

In a first embodiment of the present invention, a battery pack is provided that includes:

(a) a plurality of battery cells electrically connected in series, the plurality of battery cells including a selected battery cell, and

(b) a shorting mechanism operable, upon the occurrence of a selected event, to automatically remove electrically the selected battery cell from the electrically connected battery cells.

The selected event is commonly at least one of the following:

(i) an internal resistance of the battery cell being in excess of a first selected operating threshold;

(ii) an internal pressure of the battery cell being in excess of a second selected operating threshold;

(iii) an internal temperature of the battery cell being in excess of a third selected operating threshold;

(iv) a voltage of the battery cell during energy removal being in excess of a fourth selected operating threshold; and

(v) a voltage of the battery cell during charging being less than a fifth selected operating threshold.

By removing individual battery cells from the battery pack in the event that the internal resistance or other internal operating characteristic of the battery cell changes beyond specified limits adversely impacting the operation of the battery, the present invention can reduce the risk of battery fires, increase the effective lifetime of the battery pack, and provide a higher effective battery pack energy output over time. The shorting mechanism commonly does not reduce the maximum battery peak current. Depending on the number of cells in the battery pack, there may be a small reduction in battery pack voltage and battery pack ampere-hour capacity. The reduced voltage and storage capacity will commonly not significantly impact battery pack performance.

There are number architectures for implementing the present invention.

In a first configuration, the shorting mechanism includes a piston having a position that changes in response to the internal pressure, a shorting bar, and a shorting bar deployment member. When the internal pressure rises above a selected operating threshold, the position of the piston causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

In a second configuration, the shorting mechanism includes a thermally expansive material having a length that increases in direct response to the internal temperature, a shorting bar, and a shorting bar deployment member. When the internal temperature rises above a selected operating threshold, the length of the thermally expansive material causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

In a third configuration, the shorting mechanism includes a shorting bar, a sensor that senses the occurrence of a selected event, a controller in communication with the sensor, and a shorting bar deployment member. When the controller determines from sensor input that the selected event has occurred, the controller causes the shorting bar deployment member

to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

The first and second configurations are particularly desirable. They can be low cost, robust, are self-actuating and have a high degree of reliability.

These and other advantages will be apparent from the disclosure of the invention(s) contained herein.

The above-described embodiments and configurations are neither complete nor exhaustive. As will be appreciated, other embodiments of the invention are possible utilizing, alone or in combination, one or more of the features set forth above or described in detail below.

The following definitions are used herein:

A "battery cell" or "cell" is an individual sealed or vented cell comprised of one or more internal plate assemblies, each plate assembly comprised of a negative plate, a separator material and a positive plate. The battery cell may have one or more external negative and positive terminals.

A "plate pair" is the basic unit of a cell and is comprised of a negative plate, a separator material and a positive plate. When the separator is impregnated with an appropriate electrolyte, a voltage typical of the particular battery chemistry is developed between the positive and negative plates. In a lead-acid battery, this voltage is typically about 2.13 volts at full charge.

A "bus bar" as used herein refers to an electrical conductivity path formed by an electrically conductive bar or plate that interconnects one or more electrode terminals of a first polarity of a cell ; or one or more electrode terminals of a first polarity of a cell with one or more electrode terminals of a second polarity of a different, typically adjacent cell.

A "malfunctioning battery cell" is taken to be a cell in which there is a significant degradation of capacity or significant change in open-circuit voltage; a significant increase in internal plate resistance; and/or significant internal shorting in one or more plate pairs, any of which may cause a cell to degrade in performance or fail.

"At least one", "one or more", and "and/or" are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions "at least one

of A, B and C", "at least one of A, B, or C", "one or more of A, B, and C", "one or more of A, B, or C" and "A, B, and/or C" means A alone, B alone, C alone, A and B together, A and C together, B and C together, or A, B and C together.

## BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a side view of two possible mechanisms for automatically shorting out battery cells;

Figure 2 shows a top view of a mechanism for automatically shorting out battery cells; and

Figure 3 shows a top view of a motorized mechanism for automatically shorting out battery cells.

## DETAILED DESCRIPTION

Large energy storage batteries typically are constructed with all the plate pairs in parallel to maximize output discharge current. Other batteries, such as for example an automotive starter battery may be comprised of several plate pairs in series or in parallel or combinations thereof. In the example of an automotive starter battery, the open circuit voltage across the terminals is approximately 6 times the number of internal series connected plate pairs. Most battery cells include one or more vents which allow excess gas generated for example during an equalization charge to be discharged when a predetermined internal pressure is exceeded.

It is possible to automatically electrically short out one or more battery cells using an external bus bar that can be automatically caused to short out the external terminals of a battery cell. A preferred method of hard shorting a cell would be outside the cell thus eliminating the resistance of the terminals and internal bus bars of the cell.

Figure 1 shows a side view of two possible mechanisms for automatically moving an external bus bar to cause a by-pass shunt of a battery cell. The battery cell is comprised of a case 201 which contains a series 202 of positive and negative plates pairs separated by electrolyte. The present invention is directed towards cells in which the internal plate pairs are electrically connected in parallel although the invention may be applied to cells in which the internal plate pairs are electrically connected in series or in combinations of series and

parallel groups. It is preferable to apply the present invention to shunt a cell where the open circuit voltage is low such as for example a cell where all the plate pairs are connected electrically in parallel. While the present invention may be applied to cells with higher terminal-to-terminal open circuit voltage, the higher the terminal-to-terminal voltage, the more likely it is for inadvertent shorting to occur due to, for example, dust and other types of contamination collecting between the terminals or bus bars and the shorting bar. There is typically a headroom space 203 above the assembly 202 to allow for gases to collect. A first shorting mechanism 210 is based on an element 213 that is made of a material that has a large thermal expansion coefficient relative to the other components so that the element 213 becomes longer relative to the other components as the internal battery temperature increases. Thus internal battery temperature is the event that activates this shorting mechanism. The element 213 may be comprised, for example, of a material with an anomalously high expansion coefficient or it may be a sealed cylinder that expands when an enclosed liquid or gas lengthens the cylinder as the enclosed liquid or gas is heated by exposure to the temperature in the cell. The element 213 is fixed to a housing 212 which is in turn attached to the top of the battery case 201. When the element 213 expands relative to the other components of the shorting mechanism, it pushes on a screw mechanism 214 which is attached to a shorting bar 211. The shorting bar 211 is located on the outside of the case 201 and is shown in a top view in Figure 2. When the element 213 expands, it forces the screw mechanism 214 to rotate a small amount which in turn rotates the shorting bar. The element 213 is directly exposed to the internal temperature of the battery and when the internal temperature reaches a predetermined threshold, the shorting bar 211 is caused to rotate sufficiently to contact the positive and negative bus bars (as shown in Figure 2) thereby shorting out the cell and forming a shunt by-pass. Since the cell plate pairs are electrically connected preferably in parallel, there is voltage difference between the positive and negative bus bars of typically a few volts to a few tens of volts and the amount of rotation required to short out the battery is typically between about 5 and 10 degrees.

A second shorting mechanism 220 is based on a piston 223 that moves in response to internal battery pressure so that the piston 223 pushes upwards as the internal battery pressure increases. The piston 223 is free to move within a housing 212 which is in turn attached to the top of the battery case 201. When the piston 223 moves upward, it pushes on

a screw mechanism 224 which is attached to a shorting bar 221. The shorting bar 221 is located on the outside of the case 201 and is shown in a top view in Figure 2. When the piston 223 moves upward, it forces the screw mechanism 224 to rotate a small amount which in turn rotates the shorting bar 221. The piston 223 is directly exposed to the internal pressure of the battery and when the internal pressure reaches a predetermined threshold, the shorting bar 221 is caused to rotate enough to contact the positive and negative bus bars (as shown in Figure 2) thereby shorting out the battery cell. Thus internal battery pressure is the event that activates this shorting mechanism. Since the battery plate pairs are electrically connected preferably in parallel, there is voltage difference between the positive and negative bus bars of typically a few volts to a few tens of volts and the amount of rotation required to short out the battery is typically between about 5 and 10 degrees. Many batteries have vents (not shown) to relieve internal pressure that is built up by evolving gases. Internal pressure is most typically generated at end of charge cycle due to electrolysis or during normal hybrid electric vehicle ("HEV") charge-discharge cycling. In these cases, the change in pressure will be slow. The vents used in the present invention can be throttled to allow small amounts of gas to escape slowly. When gas pressure builds up rapidly such as for example when the internal plate pair resistances increase substantially, the vents cannot remove gas fast enough to prevent pressure build-up. The piston 223 is then exposed to enough pressure to rotate the shorting bar 221 so that it shorts out the battery cell, thereby substantially reducing the current flow across the electrode plates where the excess energy is being generated. Additionally, the shorting bars 211 and 221 can contain a fuse element that would disrupt the short circuit in the event the battery cell retains a substantial undetected charge. Finally, both mechanisms preferably include a ratchet mechanism (not shown) so that a shorting bar that makes contact with both bus bars so as to form a by-pass shunt, will remain in its final shunt position when the internal pressure and/or temperature that activates the motion of the shorting bar decreases. It is possible that when a cell is shorted out with a shunt by-pass that the current passing through the shorting bar will fuse or weld the contacts between the shorting bar and the bus bars. However, a ratchet mechanism ensures that this contact, once made, will remain.

Figure 2 shows a top view of a mechanism for manually or automatically shorting out large battery cells. In this example, a bus bar connects several terminals of a given polarity

so as to lower the overall terminal resistance. This view shows battery cell container 301 which houses three battery cells 306, 307 and 308. Bus bar 302 forms a positive terminal and connects the positive plates of battery cell 306. Bus bar 305 connects the negative plates of battery cell 306 with the positive plates of battery cell 307. Bus bar 304 connects the negative plates of battery cell 307 with the positive plates of battery cell 308. Bus bar 303 forms a negative terminal and connects the negative plates of battery cell 306. Thus the three battery cells are connected in series in this example. As can be readily seen, the negative and positive polarities can be reversed. Shorting bars 311, 312 and 313 are shown and each can rotate independently about a center post such as 314. The center posts 314 are solidly attached to each shorting bar and correspond to the screw mechanisms 214 and 224 shown in Figure 1. The shorting bar 311 is shown in contact with bus bars 302 and 305 thereby shorting out the battery cell 306. The shorting bars 312 and 313 are shown not in contact with any of the bus bars so that battery cells 307 and 308 are not shorted out. In this example therefore, two battery cells 307 and 308 are shown electrically connected in series with battery cell 306 bypassed by the shorting bar 311. The shorting bars may be rotated into contact with the main current carrying bus bars by either of the mechanisms 210 or 220 illustrated in Figure 1.

Figure 3 shows a top view of a motorized mechanism 413 for automatically shorting out battery cells. The motorized mechanism 413 is preferably mounted on the outside of the battery cell to avoid exposure to corrosive gases that typically collect in the interior of the cell. This view shows two cells 401 and 402. Bus bar 403 forms a positive terminal and connects the positive plates of battery cell 401. Bus bar 404 connects the negative plates of battery cell 401 with the positive plates of battery cell 402. Bus bar 405 connects the negative plates of battery cell 402 with the positive plates of next battery cell in the series (not shown). Thus the two battery cells are connected in series in this example. As can be readily seen, the negative and positive polarities can be reversed. Shorting bars 411 and 415 are shown and each can rotate independently about a center post such as 412. The center posts 412 are solidly attached to each shorting bar. A small motor 413 is shown connected to the center posts 412 in this example by a belt drive 414. The motor 413 may be powered by any number of electrical sources including by the power used to operate a battery monitoring system (not shown) or by power in the cell on which the motor is mounted or

from one or more of the other cells in the battery pack. The belt drive 414 is one of many well-known means for a motor 413 to rotate a shorting bar 411 about a center post 412. The shorting bar 411 shown in contact with bus bars 403 and 404 thereby shorting out the battery cell 401. The shorting bar 415 is shown not in contact with any of the bus bars so that battery cell 402 is not shorted out. Alternately, a motorized mechanism may be used to engage a shorting bar with bus bars by moving the shorting bar in a linear motion until contact is made with the bus bars.

The motorized mechanism described above may be actuated by a sensor which detects any of a number of cell parameters such as for example an anomalously high internal cell pressure, an anomalously high internal cell temperature, an anomalously high internal cell resistance, an anomalously high cell voltage during charging and/or an anomalously low cell voltage during normal discharging, where the anomalously low cell voltage during normal discharging may be of reversed polarity from its normal polarity. Any of these may be monitored by a sensor placed on or near the cell and the sensor monitored by a controller which can activate the motorized mechanism and cause it to short out the cell.

The above inventions are directed to use in a large battery pack where all the battery cells are in series. When a cell or cells develop an anomalously high internal resistances or internal short or both, this can lead to reduced performance and eventually cause the battery pack to shut down. Even when the battery pack is shut down, the defective cell or cells retain enough residual heat to eventually overheat to the point of causing a cell meltdown or a battery pack fire.

A number of variations and modifications of the invention can be used. It would be possible to provide for some features of the invention without providing others. For example in one alternative embodiment, a small amount of propellant can be contained within in a mechanism, that when a selected temperature is exceeded, initiates the propellant to generate gases which move a piston that in turn pushes on a screw mechanism that causes an external shorting bar to rotate a small amount to short out the cell. In this embodiment, internal battery temperature is the event that activates this shorting mechanism. In another alternative embodiment, a small arms or rifle primer can be contained within in a mechanism, that when a selected internal cell pressure or temperature is exceeded, fires the primer to generate gas which then moves a piston that in turn pushes on a screw mechanism that causes an external

shorting bar to rotate a small amount to short out the cell. In this embodiment, internal battery temperature and/or pressure is the event that activates the shorting mechanism. Alternately, a propellant or primer can be initiated by a controller that has sensed any of a number of selected events such as cell pressure, temperature, resistance, or voltage that is out of its normal range.

In yet another embodiment, the shorting bar may move in a nonrotational manner. For example, the bar may move horizontally or vertically in any of the above embodiments, such as about a fulcrum. One end of the bar may always be in contact with the first bus bar while the other end is moved rotationally or nonrotationally into contact with the second bus bar.

In yet a further embodiment, shorting is effected by activating a switch electrically connected to the opposite polarity bus bar(s) of one or more battery cells.

The present invention, in various embodiments, includes components, methods, processes, systems and/or apparatus substantially as depicted and described herein, including various embodiments, subcombinations, and subsets thereof. Those of skill in the art will understand how to make and use the present invention after understanding the present disclosure. The present invention, in various embodiments, includes providing devices and processes in the absence of items not depicted and/or described herein or in various embodiments hereof, including in the absence of such items as may have been used in previous devices or processes, e.g., for improving performance, achieving ease and\or reducing cost of implementation.

The foregoing discussion of the invention has been presented for purposes of illustration and description. The foregoing is not intended to limit the invention to the form or forms disclosed herein. In the foregoing Detailed Description for example, various features of the invention are grouped together in one or more embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the following claims are hereby incorporated into this Detailed Description, with each claim standing on its own as a separate preferred embodiment of the invention.

Moreover, though the description of the invention has included description of one or more embodiments and certain variations and modifications, other variations and modifications are within the scope of the invention, e.g., as may be within the skill and knowledge of those in the art, after understanding the present disclosure. It is intended to obtain rights which include alternative embodiments to the extent permitted, including alternate, interchangeable and/or equivalent structures, functions, ranges or steps to those claimed, whether or not such alternate, interchangeable and/or equivalent structures, functions, ranges or steps are disclosed herein, and without intending to publicly dedicate any patentable subject matter.

<u>What is claimed is</u>:

1. A battery pack, comprising:

a plurality of battery cells electrically connected in series, the plurality of battery cells including a selected battery cell; and

a shorting mechanism operable, upon the occurrence of a selected event, to automatically remove electrically the selected battery cell from the electrically connected battery cells.

2. The battery pack of claim 1, wherein the selected event is at least one of the following:

(i) an internal resistance of the battery cell in excess of a first selected operating threshold;

(ii) an internal pressure of the battery cell in excess of a second selected operating threshold;

(iii) an internal temperature of the battery cell in excess of a third selected operating threshold;

(iv) a voltage of the battery cell during energy removal in excess of a fourth selected operating threshold; and

(v) a voltage of the battery cell during charging less than a fifth selected operating threshold.

3. The battery pack of claim 2, wherein the event is event (i).

4. The battery pack of claim 2, wherein the event is event (ii).

5. The battery pack of claim 2, wherein the event is event (iii).

6. The battery pack of claim 2, wherein the event is event (iv).

7. The battery pack of claim 2, wherein the event is event (v).

8. The battery pack of claim 1, wherein the shorting mechanism comprises a shorting bar, a sensor that senses the occurrence of the selected event, a controller in communication with the sensor, and a shorting bar deployment member, wherein, when the controller determines from sensor input that the selected event has occurred, the controller causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

9. The battery pack of claim 4, wherein the shorting mechanism comprises a piston having a position that changes in response to the internal pressure, a shorting bar, and a shorting bar deployment member, wherein, when the internal pressure rises above the selected operating threshold, the position of the piston causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

10. The battery pack of claim 5, wherein the shorting mechanism comprises a thermally expansive material having a length that increases in direct response to the internal temperature, a shorting bar, and a shorting bar deployment member, wherein, when the internal temperature rises above the selected operating threshold, the length of the thermally expansive material causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

11. A system, comprising:

a plurality of battery cells electrically connected in series, the plurality of battery cells including a selected battery cell;

an electric motor in electrical communication with the battery cells; and

a shunting device operable in a first mode not to shunt a selected battery cell and in a second mode to shunt the selected battery cell, whereby, in the first mode, the selected battery cell provides electrical energy to the electric motor and, in the second mode, the selected battery cell provides no electrical energy to the electric motor.

12. The system of claim 11, wherein the shunting device is operable, when the selected battery cell has at least one of an internal resistance, an internal pressure, and an internal temperature in excess of a selected operating threshold, to operate in the second mode.

13. The system of claim 12, wherein the at least one of an internal resistance, an internal pressure, and an internal temperature is internal resistance.

14. The system of claim 12, wherein the at least one of an internal resistance, an internal pressure, and an internal temperature is internal pressure.

15. The system of claim 12, wherein the at least one of an internal resistance, an internal pressure, and an internal temperature is internal temperature.

16. The system of claim 11, wherein the shunting mechanism comprises a shorting bar, a sensor that senses the at least one of an internal resistance, an internal pressure, and an internal temperature, a controller in communication with the sensor, and a shorting bar deployment member, wherein, when the controller determines from sensor input that the at least one of an internal resistance, an internal pressure, and an internal temperature is above a selected operating threshold, the controller causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

17. The system of claim 13, wherein the shunting mechanism comprises a piston having a position that changes in response to the internal pressure, a shorting bar, and a shorting bar deployment member, wherein, when the internal pressure rises above a selected operating threshold, the position of the piston causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

18. The system of claim 14, wherein the shunting mechanism comprises a thermally expansive material having a length that increases in direct response to the internal temperature, a shorting bar, and a shorting bar deployment member, wherein, when the internal temperature rises above a selected operating threshold, the length of the thermally expansive material causes the shorting bar deployment member to position the shorting bar in contact with positive and negative bus bars of the selected battery cell, thereby shorting out the cell and forming a shunt bypass of the selected battery cell.

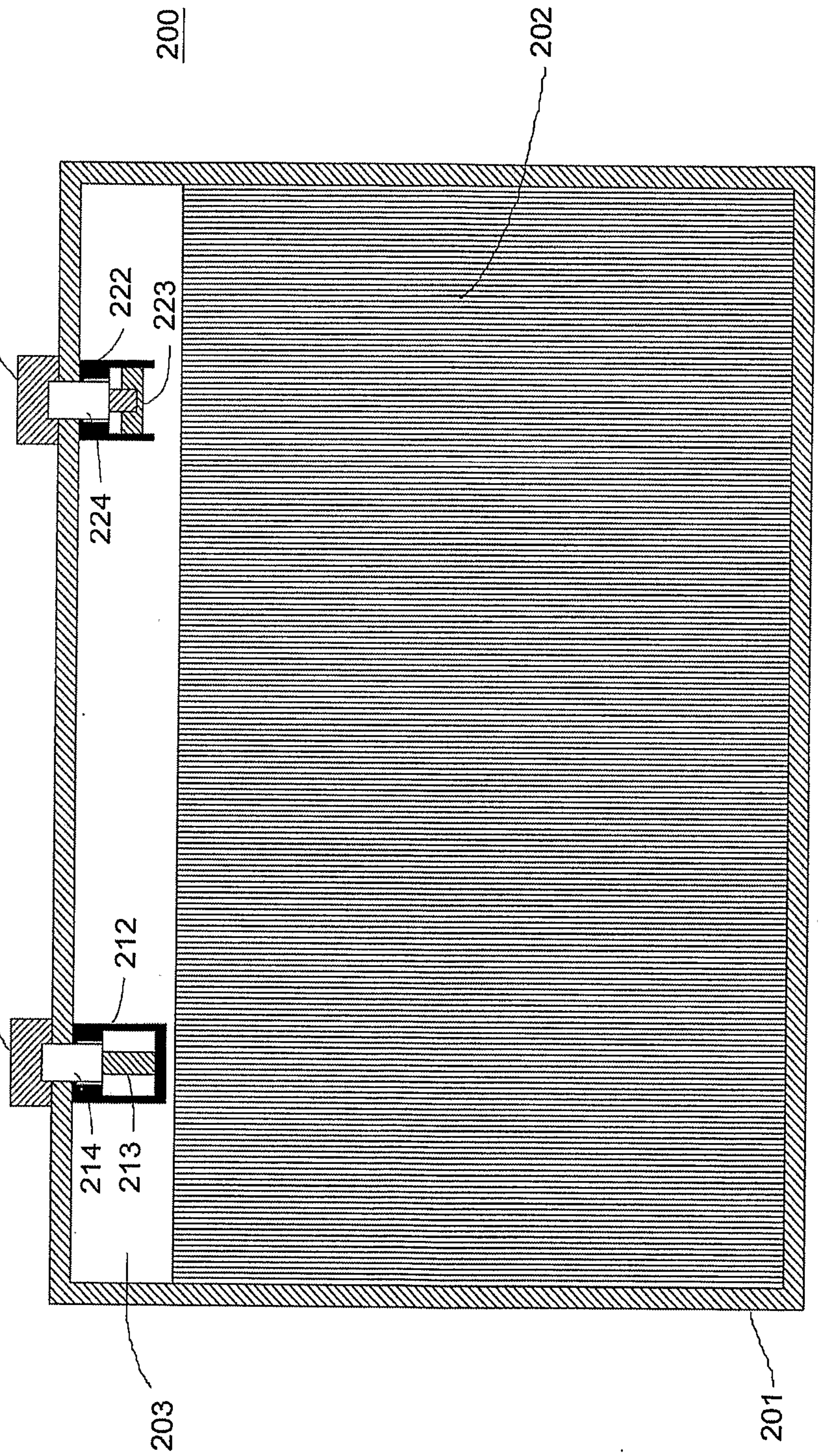


Figure 1

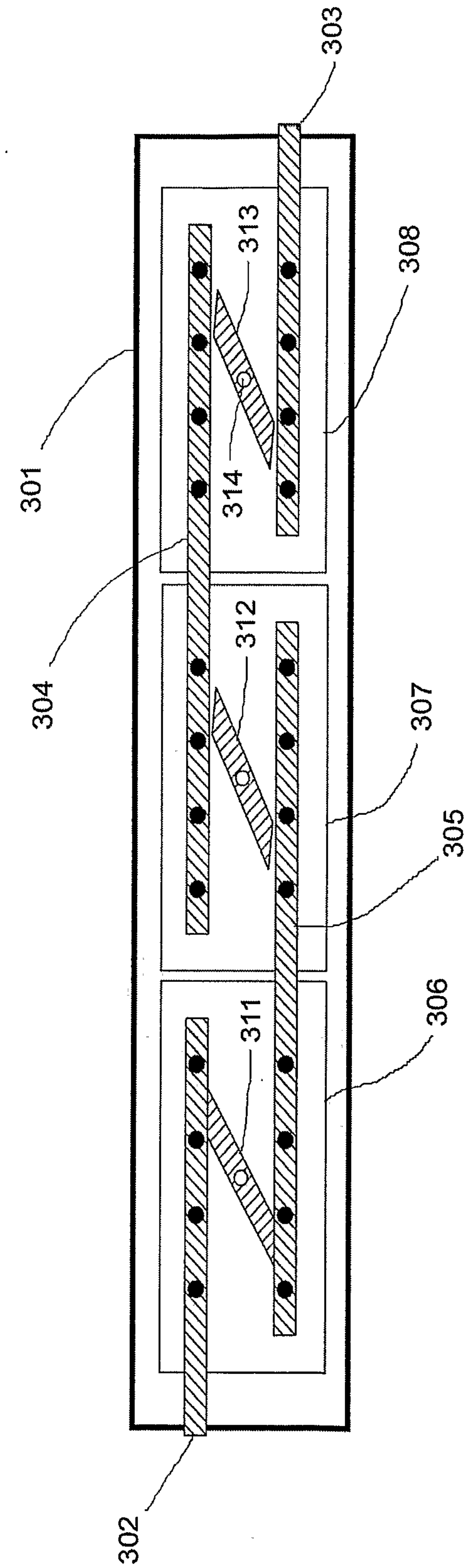


Figure 2

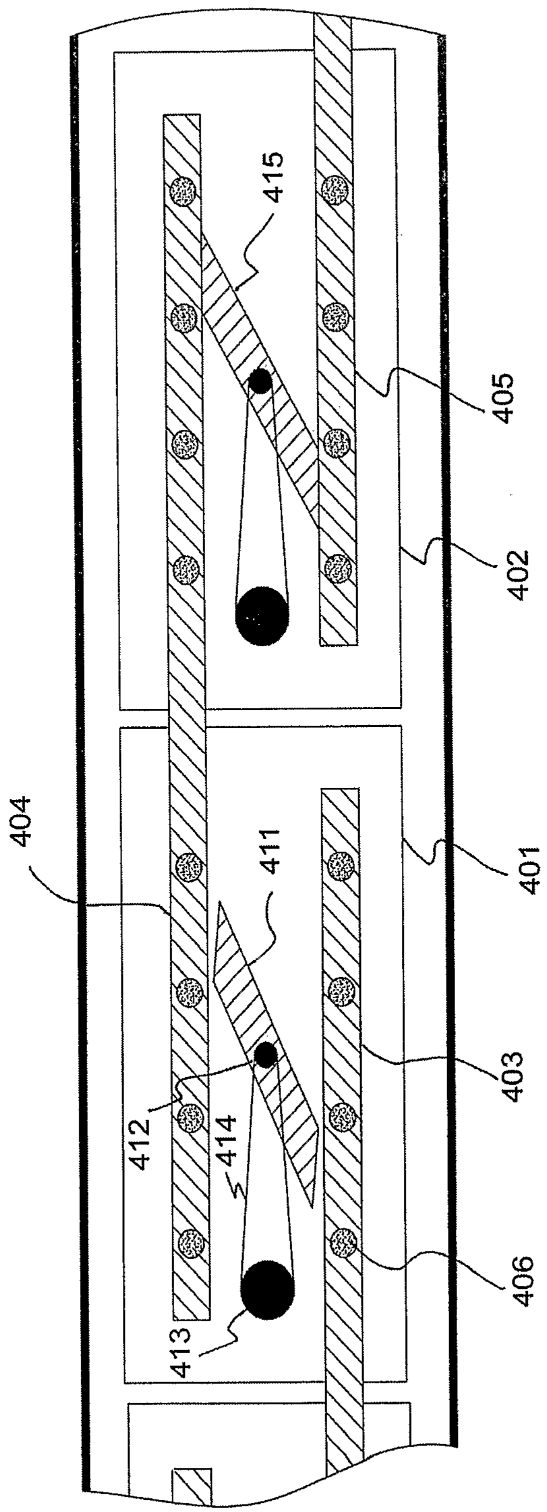


Figure 3

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US05/17392

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : H02J 7/00
US CL : 320/122

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
U.S . 320/122, 150

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 6,417,646 B1 (HUYKMAN et al.) 9 July 2002 (09.07.2002), the whole disclosure | 1-3,8,11-13,16 |

☐ Further documents are listed in the continuation of Box C ☐ See patent family annex.

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
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| 04 October 2005 (04 10.2005) | 08 NOV 2005 |
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